Asymptomatic carotid artery stenosis and stroke in patients undergoing cardiopulmonary bypass

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Purpose: **This study was undertaken to assess the natural history of carotid artery stenosis in patients undergoing cardiopulmonary bypass (CPB) at a Veterans Administration Medical Center.**

Methods: **Between January 1989 and August 1993, all patients undergoing CPB were offered preoperative carotid artery ultrasound screening as part of an investigative protocol. Patients were monitored in-hospital for the occurrence of perioperative neurologic deficit.**

Results: **A total of 582 patients underwent carotid artery ultrasound screening. Greater than 50% stenosis or occlusion of one or both internal carotid arteries was present in 130 patients (22%), with 80% or greater stenosis or occlusion of one or both arteries present in 70 patients (12%). In-hospital stroke or death occurred in 12 (2.1%) and 36 (6.2%) patients, respectively. Of the 12 strokes, five were global and seven were hemispheric in distribution. Of the five patients who had global events, none had evidence of carotid artery stenosis. However, of the seven patients who had hemispheric events, five had significant 50% or greater stenosis or occlusion of the internal carotid artery ipsilateral to the hemispheric stroke. Therefore the presence of carotid artery stenosis or occlusion was significantly associated with hemispheric stroke (no stenosis 0.34% vs stenosis 3.8%; $p = 0.0072$). Furthermore, the risk of hemispheric stroke in patients with unilateral 80% to 99% stenosis, bilateral 50% to 99% stenosis, or unilateral occlusion with contralateral 50% or greater stenosis was 5.3% (4 of 75). No strokes occurred in patients with unilateral 50% to 79% stenosis ($n = 52$).**

Conclusions: **It is concluded that carotid atherosclerosis is a risk factor for hemispheric stroke in patients undergoing CPB. (J VASC SURG 1995;21:146-53.)**

The incidence of major neurologic complications in patients undergoing cardiopulmonary bypass (CPB) ranges from 1% to 6%, depending on the patient population and method of reporting.[1-15] More subtle neurologic deficits are undoubtedly more frequent but are difficult to quantitate.[10,12,16-18] The cause of neurologic complications is unknown but is believed to be due to a combination of cerebral hypoperfusion, carotid embolic events,[5,11] aortic embolic events,[19] or air microembolism from the bypass circuit.[12,19,20] Some investigators have found a significant correlation between the presence of carotid artery stenosis and postoperative stroke,[5,8,11,21,22] and this association has led to the advocation of preoperative or simultaneous carotid endarterectomy for patients with significant carotid atherosclerosis undergoing CPB.[5,8,21,23-31] Because there appears to be a renewed interest in the performance of carotid endarterectomy in symptom-free patients,[32,33] the need for careful consideration of the risk of postoperative stroke in patients with carotid artery disease arises. The purpose of this study was to evaluate the incidence and natural history of carotid artery atherosclerosis in symptom-free patients undergoing CPB procedures at a Veterans Administration Medical Center.

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METHODS

From January 1989 to August 1993, patients undergoing CPB procedures at the Asheville VA Medical Center were offered carotid artery ultra-

sound screening as part of an investigative protocol. Patients with recent neurologic symptoms were excluded, although patients with a remote history of neurologic symptoms, cerebrovascular accident, or carotid endarterectomy were included. Patients undergoing urgent or emergency operations were also excluded.

Ultrasound examinations were performed by a total of three experienced vascular technologists. A bidirectional continuous-wave Doppler ultrasonic velocity detector with 7.2 MHz probe (Carolina Medical Instruments, Winston-Salem, N.C.) dedicated to the study of carotid arteries was used. Color-flow imaging was added in 1991. Percent stenosis was estimated by a combination of peak systolic frequency and duplex-graded plaque size. Arteries were characterized by degree of wall thickness (mild, moderate, or severe), degree of internal carotid artery (ICA) stenosis (0% to 100%), the presence of plaques or ulcers, the presence of antegrade vertebral artery flow, and peak systolic frequency in each of the proximal, mid, and distal common carotid artery and ICA, the carotid bifurcation, and the proximal and distal external carotid artery. The results of the studies were available to all medical personnel, and written reports became part of the permanent medical record.

Preoperative and intraoperative variables were recorded by perfusionists during and after the completion of the operative procedure. In-hospital follow-up and data recording were also performed by perfusionists. All charts of patients with neurologic events were retrospectively re-reviewed by either the first or senior author or both. Strokes were considered either global or hemispheric depending on the clinical presentation and computed tomography (CT) findings, or, if CT was not available, on the clinical findings alone. Hemispheric strokes were considered "appropriate to the side of the lesion" when 50% or greater ICA stenosis or occlusion was noted before operation on the same side of a subsequent hemispheric stroke.

The data were entered into standard database and statistical software packages. Data are represented as mean ± SEM except when otherwise indicated. Continuous variables were considered normally distributed and were analyzed by use of Student's t test; discrete variables were analyzed by use of Fisher's exact test. Multivariate analysis was performed via stepwise logistic regression for multivariate models. Because of the large number of statistical comparisons calculated, p values less than 0.01 were considered significant.

RESULTS

Of 977 CPB procedures performed between January 1989 and August 1993, 582 (60%) were preceded by carotid artery ultrasound examination (Table I). Patients undergoing ultrasound examinations greater than 6 months before operation (n = 9) or in the postoperative period (n = 43) were excluded. Percentage enrollment in the study was low in the first year because of limited availability of ultrasound technologists, but enrollment increased to nearly 90% during the final year (Table I). The examinations were performed a median of 5 days before surgery with a range of 1 to 175 days (mean and SD 11 ± 18 days).

Preoperative, intraoperative, and postoperative characteristics for the screened group are shown in Table II. In-hospital stroke or death occurred in 12 (2.1%) and 36 (6.2%) patients in the screened group, respectively, which was not significantly different from the incidence of stroke and death in the total population (stroke 1.5% and death 7.0% in 977 patients).

The overall incidence of 50% or greater stenosis or occlusion of one or both ICAs in the screened group was 22% (130 of 582 patients) (Table III). Seventy patients (12%) had 80% or greater stenosis or occlusion of one or both ICAs, and 50 (8.6%) had bilateral 50% or greater lesions. The presence of unilateral occlusion was found in 21 patients (3.6%), and eight patients (1.4%) had unilateral occlusion with contralateral 50% or greater stenosis.

Major neurologic events occurred in 12 patients who underwent carotid artery ultrasound screening (Table IV). Overall, there were five global strokes and seven hemispheric strokes, three right-sided and four left-sided (Table V). Nine patients underwent CT scanning after stroke, and the clinical findings were supported by CT in all cases. Three deficits were transient, one partially resolved while the patient was in the hospital, and eight were permanent. Four patients were discharged to home, three were discharged to a long-term care facility, and five patients died.

The global and hemispheric stroke rates for subgroups of patients according to the severity of carotid artery disease is shown in Table III. The hemispheric stroke rate ranged from 0.34% for patients without significant carotid artery disease (2 of 452) to 3.8% for patients with 50% or greater stenosis or occlusion of one or both ICAs (5 of 130) to 8.3% for patients with bilateral 80% to 99% stenosis (1 of 12). No strokes occurred in patients with unilateral 50% to 79% stenosis (n = 52). The

Table I. Carotid artery duplex examinations by year

Year	*No. of Cases*	*No. of Examinations (%)*
1989	257	63 (24%)
1990	193	140 (72%)
1991	190	123 (67%)
1992	180	128 (64%)
1993 (Jan-Aug)	157	128 (89%)
Total	977	582 (60%)

Table II. Characteristics of 582 patients undergoing carotid artery duplex examinations and cardiopulmonary bypass

Characteristic	*Total patients*	*Positive respondents*	
		%	*Mean ± SD (range)*
Age	581		62 ± 8 (32-82)
Male sex	582	581 (99%)	
White race	579	566 (98%)	
NYHA class	529		3.6 ± 0.6 (1-4)
History of MI	530	371 (70%)	
No. vessels involved	554		2.9 ± 1.1 (0-8)
Left main disease	546	137 (25%)	
Ejection fraction (%)	521		48 ± 10 (20-80)
Smoking	509	280 (55%)	
Hypertension	511	295 (58%)	
Diabetes	512	128 (25%)	
Family history of coronary artery disease	474	302 (64%)	
Family history of cerebrovascular disease	468	52 (11%)	
Prior vascular surgery	509	63 (12%)	
Prior carotid endarterectomy	509	26 (5%)	
Prior cerebrovascular symptoms	502	48 (10%)	
Aspirin use	524	448 (85%)	
Presence of cervical bruit(s)	506	73 (14%)	
Presence of peripheral vascular disease	502	55 (11%)	
Nonsinus rhythm	508	29 (6%)	
Q-waves on preoperative EKG	498	86 (17%)	
CABG only	582	520 (89%)	
Redo procedure	574	55 (10%)	
Cross-clamp time (min)	576		60 ± 39 (5-491)
CPB time (min)	572		135 ± 64 (14-911)
Minimum myocardial temperature (° C)	562		7.7 ± 2.6 (1.8-30)
Postoperative inotrope use	499	345 (69%)	
Postoperative vasoconstrictor use	495	310 (63%)	
Postoperative antidysrhythmic use	494	245 (50%)	
Postoperative IABP use	503	36 (7%)	
Return to OR	500	30 (6%)	
Any stroke (global or hemispheric)	582	12 (2.1%)	
Hemispheric stroke	582	7 (1.2%)	
In-hospital death	582	36 (6.2%)	

NYHA, New York Heart Association; *MI,* myocardial infarction; *EKG,* electrocardiogram; *CABG,* coronary artery bypass grafting; *IABP,* intraaortic balloon pump; *OR,* operating room.

combined group of patients with unilateral 80% to 99% stenosis, bilateral 50% or greater stenosis, or unilateral occlusion with contralateral 50% or greater stenosis exhibited a hemispheric stroke rate of 5.3% (4 of 75), which was statistically significantly greater than the risk of stroke in patients not having one of these disease patterns (0.59%, 3/507; $p = 0.003$).

Because of the small number of strokes in the total series, valid statistical comparison among all subgroups was precluded. It was possible, however, to compare reliably those patients without evidence of significant carotid artery disease (NOSTEN, $n = 452$) with those patients with 50% or greater stenosis or occlusion of one or both ICAs (STEN, $n = 130$). The preoperative, intraoperative, and postoperative variables previously described in Table

Table III. Carotid artery disease in 582 patients undergoing carotid artery duplex examinations and CPB

Characteristic	*Positive (%)*	*Any stroke (global or hemispheric)*	*Hemispheric stroke**
Absence of any carotid artery disease (< 50% stenosis)	452 (78%)	7 (1.6%)	2 (0.34%)
≥ 50% stenosis or occlusion of one or both ICA	130 (22%)	5 (3.8%)	5 (3.8%)
≥ 80% stenosis or occlusion of one or both ICA	70 (12%)	4 (5.7%)	3 (4.3%)
80% to 99% stenosis of one or both ICA	56 (9.6%)	3 (5.4%)	2 (3.6%)
Unilateral stenosis 50% to 99% (contralateral < 50% stenosis)	67 (12%)	1 (1.5%)	1 (1.5%)
Unilateral stenosis 80% to 99% (contralateral < 50% stenosis)	25 (4.3%)	1 (4.0%)	1 (4.0%)
Unilateral stenosis 50% to 79% (contralateral < 50% stenosis)	52 (8.9%)	0	0
Occlusion of one or both ICA	21 (3.6%)	1 (4.8%)	1 (4.8%)
Unilateral occlusion (contralateral < 50% stenosis)	13 (2.2%)	1 (7.7%)	1 (7.7%)
Unilateral occlusion with contralateral ≥ 50% stenosis or occlusion	8 (1.4%)	0	0
Unilateral occlusion with contralateral 50% to 99% stenosis	8 (1.4%)	0	0
Unilateral occlusion with contralateral 80% to 99% stenosis	7 (1.2%)	0	0
Bilateral ≥ 50% stenosis or occlusion	50 (8.6%)	3 (6.0%)	3 (6.0%)
Bilateral 50% to 99% stenosis	42 (7.2%)	3 (7.1%)	3 (7.1%)
Bilateral 80% to 99% stenosis	12 (2.1%)	1 (8.3%)	1 (8.3%)
Bilateral occlusion	0	0	0
Unilateral 80% to 99% stenosis, bilateral ≥ 50% stenosis, or unilateral occlusion with contralateral ≥ 50% stenosis	75 (13%)	4 (5.3%)	4 (5.3%)
Absence of unilateral 80% to 99% stenosis, bilateral ≥ 50% stenosis, or unilateral occlusion with contralateral ≥ 50% stenosis	507 (87%)	8 (1.6%)	3 (0.59%)

*Appropriate to side with carotid artery stenosis.

Table IV. Ultrasound findings in 12 patients with post-operative stroke

				Ultrasound findings				
				Right		*Left*		
Patient	*Age*	*Procedure*	*Year*	*Stenosis (%)*	*Plaques*	*Stenosis (%)*	*Plaques*	*Stroke type*
1	61	CABG	1989	30	No	30	No	R hemispheric
2	70	CABG/AVR	1989	70-80	Yes	60-70	Yes	L hemispheric
3	69	Redo CABG	1989	80	Yes	50	Yes	L hemispheric
4	57	CABG	1989	80	Yes	80	Yes	L hemispheric
5	58	Redo CABG	1990	0	No	0	Yes	L hemispheric
6	69	CABG	1990	0	Yes	30	Yes	Global
7	66	CABG	1990	0	Yes	0	Yes	Global
8	68	CABG	1990	0	No	0	No	Global
9	62	CABG	1991	95	Yes	0	Yes	R hemispheric
10	74	CABG, TAA repair	1992	100	Yes	30	Yes	R hemispheric
11	65	Redo CABG	1993	0	No	0	No	Global
12	69	CABG	1993	0	No	0	No	Global

CABG, Coronary artery bypass grafting; *R,* right; *AVR,* aortic valve replacement; *L,* left; *TAA,* thoracoabdominal aneurysm.

II were applied to the NOSTEN and STEN groups in a univariate fashion to determine whether any characteristics were associated with carotid artery stenosis. The results are shown in Table VI. The STEN group had a significantly higher mean, age as well as an increased frequency of prior vascular surgery, prior carotid artery surgery, prior cerebrovascular symptoms, cervical bruit(s), and peripheral vascular disease ($p < 0.01$). The incidence of stroke (global or hemispheric) or death was not statistically different in the NOSTEN and STEN groups. However, the incidence of hemispheric stroke was statistically significantly greater in the STEN group than the NOSTEN group (STEN 3.8% vs NOSTEN 0.34%; $p = 0.0072$).

The in-hospital mortality rate for the screened group of 582 patients was 6.2%. With univariate analysis, death was significantly associated with longer CPB time ($p = 0.0002$), the use of postoperative antidysrhythmic agents ($p = 0.0046$), the use of intraaortic balloon counterpulsation ($p = 0.00001$), and the presence of global or hemispheric stroke ($p = 0.00001$). With multivariate analysis, only the use of postoperative antidysrhythmic agents

Table V. Clinical course in 12 screened patients with postoperative stroke

Patient	*Day*	*Symptoms*	*CT scan findings*	*Duration*	*Outcome*
1	1	R leg weakness, unresponsiveness	ND	Transient	Discharged to home
2	2	R hemiparesis, aphasia	ND	Transient	Discharged to home
3	4	R hemiparesis, aphasia	L frontoparietal infarction	Permanent	Reexplored for bleeding, discharged to long-term care facility
4	1	R hemiparesis, aphasia	L frontal infarction	Partially resolved	Discharged to home
5	2	R hemiparesis, psychosis	ND	Transient	Discharged to home
6	1	Coma	Bilateral diffuse infarction	Permanent	Discharged to long-term care facility
7	2	Coma	Diffuse cerebellar infarction	Permanent	Pneumonia, death
8	1	L hemiparesis, lethargy	Diffuse infarction	Permanent	Peripheral atheroembolism, kidney failure, mesenteric infarction, death
9	1	L hemiparesis	R parieto-occipital infarction	Permanent	VT, heart failure, death
10	3	L hemiparesis	R frontal infarction	Permanent	Discharged to long-term care facility
11	1	Coma	Diffuse infarction	Permanent	Peripheral atheroembolism, kidney failure, death
12	4	Blunted affect, dysphagia	Diffuse infarction	Permanent	Psychosis, failure to thrive, gastrointestinal hemorrhage, death

R, Right; *ND,* not done; *L,* left; *VT,* ventricular tachycardia.

Table VI. Preoperative predictors and postoperative outcome for carotid artery stenosis 50% or greater ($p < 0.01$)

Variable	*Carotid artery stenosis <50%*		*Carotid artery stenosis ≥50% or occlusion*		*p Value*
	Total patients	*Positive (percent) or mean ± SEM (range)*	*Total patients*	*Positive (percent) or mean ± SEM (range)*	
Preoperative predictors					
Age	451	62.1 ± 0.4 (32-82)	130	65.2 ± 0.55 (39-78)	0.0001
Prior vascular surgery	390	34 (9%)	119	29 (24%)	0.00001
Prior carotid artery surgery	390	8 (2%)	119	18 (15%)	0.00001
Prior cerebrovascular symptoms	382	27 (7%)	120	21 (18%)	0.00013
Presence of cervical bruits(s)	388	28 (7%)	118	45 (38%)	0.00001
Presence of peripheral vascular disease	386	31 (8%)	116	24 (21%)	0.00025
Outcome					
All strokes (global and hemispheric)	452	7 (1.5%)	130	5 (3.8%)	NS
Hemispheric stroke only	452	2 (0.34%)	130	5 (3.8%)*	0.0072
In-hospital death	452	25 (5.5%)	130	11 (8.4%)	NS

*Carotid artery lesions appropriate to stroke distribution.

or intraaortic balloon counterpulsation were statistically significant (Table VII).

DISCUSSION

The purpose of this study was to evaluate the presence of carotid atherosclerosis in a population of patients in the VA group undergoing CPB and to investigate the relationship between carotid atherosclerosis and postoperative neurologic complications. The population under study was a typical VA patient group undergoing heart surgery with a high incidence of comorbid conditions (Table II). The incidence of stroke, reoperation for bleeding, and death (2.1%, 6.0%, and 6.2%, respectively) was acceptable for this patient population.

A major finding in this study was the high incidence of significant carotid artery lesions; 22% of patients had stenosis of 50% or greater or occlusion in one or both ICAs. This incidence is considerably higher than previously reported figures,[2,3,5,8,34-36] the highest of which was 16.9% in a study of 520 patients compiled by Faggioli et al (Table VIII).[8]

The presence of carotid artery disease in this study was associated with a significantly higher mean age, and higher prevalence of prior vascular surgery, prior carotid artery surgery, prior cerebrovascular symptoms, the presence of cervical bruit(s), and the presence of peripheral vascular disease. Previous studies have also shown that carotid artery disease is more frequently found in patients with peripheral vascular disease.[3] The presence of a cervical bruit was positively associated with the presence of ICA stenosis in this study, but, as other investigators have noted,[2] its poor specificity limits its usefulness as a

Table VII. Variables predicting death in 582 patients undergoing carotid duplex ultrasonography and CPB

Variable	*Survivors*		*Nonsurvivors*		*p Value*
	Total patients	*Positive (percent) or mean ± SEM (range)*	*Total patients*	*Positive (percent) or mean ± SEM (range)*	
Univariate analysis					
CPB time (min.)	548	133 ± 3	23	183 ± 18	0.0002
Post-op antidysrhythmic use	474	48%	19	84%	0.0046
Post-op IABP use	482	5%	20	10%	0.00001
Stroke*	480	1%	17	24%	0.00001
Multivariate analysis					
Post-op antidysrhythmic use	—	—	—	—	0.0001
Post-op IABP use	—	—	—	—	0.0001

IABP, Intraaortic balloon pump.
*Global or hemispheric.

Table VIII. Incidence of carotid atherosclerosis and neurologic events in symptom-free patients undergoing cardiopulmonary bypass

Author	*Year*	*No.*	*Method of detection*	*Lesion severity*	*Presence of carotid artery disease*	*Incidence of stroke*
Breslau[34]	1981	78	US	≥50%	6%	0%
Brener[5]	1987	3990	OPG, US, angiography	≥50	2.1	9.4
Hertzer[26]	1989	58*	Angiography	≥70	NR	6.9†
Faggioli[8]	1990	520	US, OPG	≥50	16.9	4.5
				≥75	5.4	14.3
Berens[3]	1992	951	US	≥50	15.4	NR
Sahlman[35]	1993	99	US	≥50	4.0	0

US, Ultrasonography; *OPG,* oculoplethysmography; *NR,* not reported; *CVA,* cerebrovascular accident.
*Randomized as part of a larger cohort.
†Additional 7.5% suffered CVA at the time of subsequent endarterectomy.

clinical test. In contradistinction to other investigators,[3,34,35] however, this study failed to reveal an association between carotid artery stenosis and general systemic and cardiac risk factors, including hypertension, smoking, diabetes, myocardial infarction, and left main coronary artery disease. In this regard, the results presented herein agree with those of Faggioli et al.,[8] who found no association between asymptomatic carotid artery stenosis and systemic risk factors, including hypercholesterolemia, hypertension, diabetes, and smoking. Although not statistically significant, the mortality rate was slightly greater in patients with carotid artery stenosis (8.4% vs 5.5%), a trend also noted by other investigators.[2,5]

The major finding of this report is the relationship between significant carotid artery stenosis and hemispheric stroke. Five of seven patients who had a well-documented hemispheric stroke had preoperative evidence of significant ICA stenosis or occlusion on the side of the stroke: one patient had a 50% lesion, one had a 70% lesion, three had 80% lesions, one had a 95% lesion, and one had complete occlusion (Table V). The risk of hemispheric stroke in patients without significant stenosis was 0.34%, whereas the incidence in patients with at least one 50% or greater lesion or occlusion was 3.8% ($p = 0.0072$). Although statistical comparison among subgroups groups was precluded by the small number of events, the risk of stroke appeared to increase with increasing severity of disease. For instance, the incidence of hemispheric stroke was 3.8% for patients with 50% or greater stenosis of occlusion of one of both ICAs, 4.3% for patients with 80% or greater stenosis or occlusion, 6.0% for patients with bilateral 50% or greater stenosis or occlusion, and 8.3% for patients with bilateral 80% to 99% stenosis (1 of 12 patients). Patients with unilateral 80% to 99% stenosis, bilateral 50% or greater stenosis, or unilateral occlusion with contralateral 50% or greater stenosis, a group for which surgery might be offered in many centers, exhibited a hemispheric stroke rate of 5.3% (4 of 75). In contrast, the stroke rate was much lower in patients with less severe disease (3 of 507, 0.59%). No patient

Table IX. Reported risk of stroke and/or death with combined endarterectomy and CPB in symptom-free patients

Author	*Year*	*No. cases*	*Stroke*		*Death (%)*
			No.	*%*	
Hertzer[25]	1983	173	14	8.1	3.5
Perler[29]	1988	30	2	6.7	13
Cambria[23]	1989	49	3	6.1	NR
Hertzer[26]	1989	71[1]	2	2.8	4.2
Faggioli[8]	1990	19	0	0	NR
Berens[3]	1992	46	3	6.5	10.9
Vermeulen[31]	1992	73	4	5.5	NR
Rizzo[36]	1992	40	0	0	NR
Total		501	28	5.6	

NR, Not reported
[1]randomized to combined endarterectomy/CPB

with unilateral stenosis 50% to 79% and a "normal" contralateral ICA had a stroke ($n = 52$).

Many previous investigators have examined the relationship between carotid atherosclerosis and stroke risk, and a summary of their findings is presented in Table VIII. Although direct comparisons with this study are limited because of the inclusion of patients with symptoms and those undergoing simultaneous CPB and carotid endarterectomy, the single largest published study involved nearly 4000 patients and reported an incidence of neurologic events of 1.9% in patients without significant carotid artery stenosis compared with 9.4% in patients with stenosis.[5] Other investigators have found stroke rates ranging from 4% to 7%, depending on the severity of lesions and the population under study. These findings, combined with the data presented in this study, indicate that the risk of hemispheric stroke after CPB is indeed related to the presence of carotid artery disease, although a large number of patients appears to be required for demonstration of this phenomenon.

Because the risk of carotid endarterectomy for isolated asymptomatic carotid artery stenosis is quite low in modern series,[33] many surgeons have advocated simultaneous endarterectomy and CPB in an attempt to decrease the neurologic complications of CPB. Although this report does not address the feasibility of combined procedures, it appears that, until the long-term benefit of endarterectomy for asymptomatic lesions is conclusively demonstrated, simultaneous endarterectomy and CPB can only be justified if a reduction in perioperative stroke rates can be achieved. According to the results presented herein, the combined procedure does not appear to be justified for 50% to 79% lesions because no strokes were observed in this group. For patients with unilateral 80% to 99% stenosis, bilateral 50% or greater stenosis, or unilateral occlusion with contralateral 50% or greater stenosis, the hemispheric stroke risk was 5.3%. Therefore, for the combined procedure to be efficacious, the risk of perioperative stroke should not exceed this level. A review of the available series on simultaneous endarterectomy and CPB reveals that the stroke risk in most centers exceeds this limit (Table IX), although the more recently published results have improved significantly, and a few centers have reported stroke rates less than 3%.[8,26,36] A higher allowable stroke rate may be appropriate for more severe forms of disease because it can be demonstrated that this group exhibits a stroke rate in excess of 5%.

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